NASA Innovative Advanced Concepts

The Fusion Driven Rocket: Nuclear Propulsion through Direct Conversion of Fusion Energy

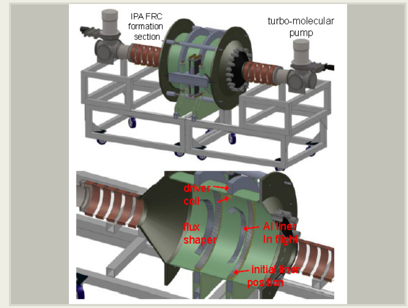
Completed Technology Project (2012 - 2014)

Project Introduction

The Fusion Driven rocket (FDR) represents a revolutionary approach to fusion propulsion where the power source releases its energy directly into the propellant, not requiring conversion to electricity. It employs a solid lithium propellant that requires no significant tankage mass, which is rapidly heated and accelerated to high exhaust velocity, while having no significant physical interaction with the spacecraft thereby avoiding damage to the rocket and limiting both the thermal heat load and radiator mass. Current nuclear fusion efforts have focused on the generation of electric grid power and are wholly inappropriate for space transportation as the application of a reactor based fusion-electric system creates a colossal mass and heat rejection problem for space application. The Fusion Driven rocket (FDR) represents a revolutionary approach to fusion propulsion where the power source releases its energy directly into the propellant, not requiring conversion to electricity. It employs a solid lithium propellant that requires no significant tankage mass. The propellant is rapidly heated and accelerated to high exhaust velocity (> 30 km/s), while having no significant physical interaction with the spacecraft thereby avoiding damage to the rocket and limiting both the thermal heat load and radiator mass.

Anticipated Benefits

The future of manned space exploration and development of space depends critically on the creation of a dramatically more efficient propulsion architecture for in-space transportation. A very persuasive reason for investigating the applicability of nuclear power in rockets is the vast energy density gain of nuclear fuel when compared to chemical combustion energy. The Fusion Driven rocket (FDR) represents a revolutionary approach to fusion propulsion where the power source releases its energy directly into the propellant, not requiring conversion to electricity.



Concept Diagram

Table of Contents

NASA Innovative Advanced Concepts

The Fusion Driven Rocket: Nuclear Propulsion through Direct Conversion of Fusion Energy

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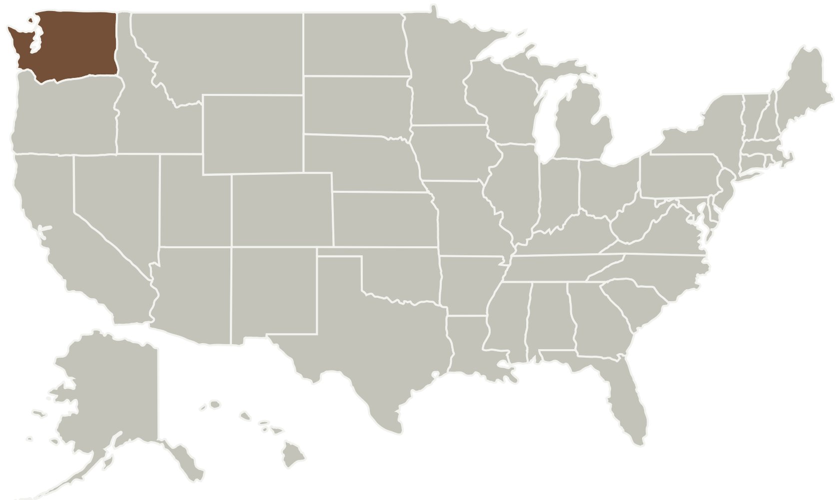
Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
MSNW, LLC	Lead Organization	Industry	Redmond, Washington
University of Washington-Seattle Campus(UW)	Supporting Organization	Academia	Seattle, Washington

Primary U.S. Work Locations
Washington

Project Transitions

September 2012: Project Start

Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Lead Organization:

MSNW, LLC

Responsible Program:

NASA Innovative Advanced Concepts

Project Management

Program Director:

Jason E Derleth

Program Manager:

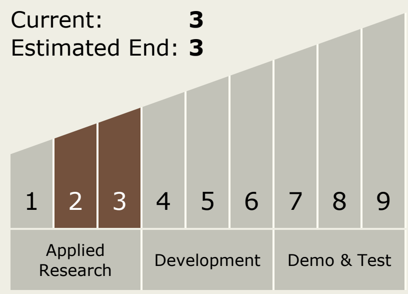
Eric A Eberly

Principal Investigator:

John Slough

Technology Maturity (TRL)

Start: **2**
Current: **3**
Estimated End: **3**



August 2014: Closed out

Closeout Summary: The future of manned space exploration and development of space depends critically on the creation of a dramatically more efficient propul sion architecture for in-space transportation. A very persuasive reason for invest igating the applicability of nuclear power in rockets is the vast energy density ga in of nuclear fuel when compared to chemical combustion energy. The Fusion Dr iven rocket (FDR) represents a revolutionary approach to fusion propulsion wher e the power source releases its energy directly into the propellant, not requiring conversion to electricity. It employs a solid lithium propellant that requires no si gnificant tankage mass. The propellant is rapidly heated and accelerated to high exhaust velocity (> 30 km/s), while having no substantial physical interaction wi th the spacecraft thereby avoiding damage to the rocket and limiting both the th ermal heat load and radiator mass. The key to achieving this stems from researc h at MSNW and the UW on the magnetically driven implosion of metal foils onto a magnetized plasma target to obtain fusion conditions. A logical extension of th is work leads to a method that utilizes these metal shells (or liners) to not only achieve fusion conditions, but to serve as the propellant as well. Several low-ma ss, magnetically driven metal liners are inductively driven to converge radially a nd axially and form a thick blanket surrounding the target plasmoid and compre ss the plasmoid to fusion conditions. Virtually all of the radiant, neutron and par ticle energy from the plasma is absorbed by the encapsulating, thick metal blan ket thereby isolating the spacecraft from the fusion. This energy, in addition to t he intense Ohmic heating at peak magnetic field compression, is adequate to va porize and ionize the metal blanket. The expansion of this hot, ionized metal pro pellant through a magnetically insulated nozzle produces high thrust at the opti mal Isp. The energy from the fusion process, along with the waste heat, is thus utilized at very high efficiency. The basic scheme for FDR is illustrated and descr ibed in the report (see Fig. 2) The two most critical issues in meeting challenges introduced employing magneto-inertial fusion as the power source is driver effici ency and stand-off - the ability to isolate and protect fusion and thruster from th e resultant fusion energy. By employing metal shells for compression, it is possi ble to produce the desired convergent motion inductively by inserting the metal sheets along the inner surface of cylindrical or conically tapered coils. Both stan d-off and energy efficiency issues are solved by this arrangement. This two year effort focused on achieving three key criteria for the Fusion Driven Rocket to mo ve forward for technological development: (1) the physics of the FDR must be fu lly understood and validated, (2) the design and technology development for the FDR required for its implementation in space must be fully characterized, and (3) an in-depth analysis of the rocket design and spacecraft integration as well a s mission architectures enabled by the FDR need to be performed. A subscale, la boratory liner compression test facility was assembled at the University of Washi ngton Plasma Dynamics Laboratory with sufficient liner kinetic energy (~ 0.5 M J) to reach conditions required for fusion breakeven conditions. Detailed experim ental studies of the dynamic behavior of the driven liners as well as liner conver gence and magnetic compression were performed. The development of both the 1D liner dynamics code and the full 3D ANSYS liner calculations was achieved. T he characterization of both the FDR and spacecraft as well as a design architectu re analysis was conducted that included an examination of a wide range of missi on architectures and destinations for which this fusion propulsion system would be enabling or critical. Inparticular a rapid, single launch manned Mars mission was developed.

Technology Areas

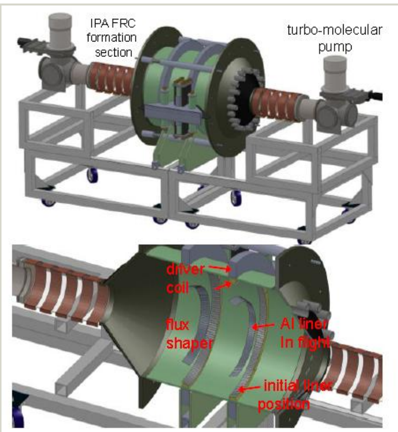
Primary:

- TX01 Propulsion Systems
  - └ TX01.4 Advanced Propulsion
    - └ TX01.4.4 Other Advanced Propulsion Approaches

Target Destination

Foundational Knowledge

Images



The Fusion Driven Rocket: Nuclear Propulsion through Direct Conversion of Fusion Energy
Concept Diagram
(https://techport.nasa.gov/image/102283)

Links

Helion Energy Achieves 100 Million Degrees Celsius Fusion Fuel Temperature and Confirms 16-Month Continuous Operation of Its Fusion Generator Prototype
(https://www.businesswire.com/news/home/20210622005366/en/Helion-Energy-Achieves-100-Million-Degrees-Celsius-Fusion-Fuel-Temperature-and-Confirms-16-Month-Continuous-Operation-of-Its-Fusion-Generator-Prototype)